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"mean precipitation-hours for the conterminous united states"

donald a. haines

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U.S. DEPARTMENT OF AGRICULTURE

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MEAN PRECIPITATION-HOURS FOR THE CONTERMINOUS UNITED STATES

Donald A. Haines

Of all of the common weather phenomena, precipitation probably exerts the strongest influence on man and his activities. Since it influences man in different ways, there are a number of ways of describing the process. Most questions about precipitation can be reduced to "How much?," for precipitation amount is of prime concern in such activities as drought measurement and snow removal. There are, however, other ways of characterizing precipitation that are equally important. Knowing maximum precipitation amounts per unit time is essential in engineering storm drains. Knowing the frequencies of expected precipitation days is of help to the farmer during haying and other harvesting operations. And there are many other activities where precipitation, or the lack of it, plays a dominant role.

In the battle against forest fire, moisture content of fuels is a vital concern. Fuel moisture content is affected by a wide range of atmospheric phenomena--i.e., humidity, temperature, insolation, wind, fog, dew, and precipitation. Fine fuels (materials less than 1/4 inch in diameter) respond rapidly to changes in most of these weather variables. Larger fuels show more gradual responses and are particularly sensitive to the absorption process during precipitation periods. Because fuels absorb water slowly, the duration of precipitation is more critical than the amount.

Simard (1968) and Fosberg (1972) found that for moisture absorption in round-wood fuel, the maximum *effective* rate of precipitation is on the order of a millimeter per day assuming continuous precipitation. Greater precipitation intensities do not result in increased absorption; the water simply runs off. For this reason the National Fire Danger Rating System (NFDRS) uses a precipitation value of 0.01 inch per hour as input (Deeming *et al.* 1972). This is the smallest amount recorded by most measurement devices. Theoretically, an even lower hourly value could be used in the system.

It would appear important to construct a climatology for this aspect of precipitation. The objective of this paper, therefore, is to present monthly, nationwide patterns of mean precipitation-hours, and as a corollary, the nationwide patterns of average precipitation-hours per precipitation-day (P.H./P.D.). There are a number of potential uses for such information. Obviously it should be of help to fire-weather forecasters, planners of prescribed burns, and others engaged in fire-behavior prediction and control efforts. But it may also be of use to agriculturists studying plant growth, pathologists studying plant and tree diseases where wetness is a critical factor, and entomologists studying environmental factors that are important in the life cycle of insects.

This type of summary does not, of course, tell anything about duration of individual storms. A summary of mean precipitation-hours should be viewed as a basic climatological tool.

DATA SOURCE AND COMPUTATIONAL PROCEDURES

A precipitation-day is defined as a 24-hour period having a precipitation amount of at least 0.01 inch. Maps of the mean monthly and annual number of days with 0.01 inch or more of precipitation have already been published for the United States (U.S. Dep. of Commerce, National Oceanic and Atmospheric Administration (NOAA) 1968). A precipitation-hour is defined as an hour having a precipitation amount of at least 0.01 inch.

A more comprehensive study might involve either computing precipitation probabilities from tabulated frequencies or fitting a mathematical function to tabulations and computing precipitation probabilities from this function. Unfortunately, the amount of basic data needed to accomplish either goal is overwhelming. For instance, if observation information were to be processed by computer, tabulation of 10 years of hourly data at any one station would necessitate an input of 24 hours X 365 days X 10 years, or a total of 87,600 punched cards. Consequently, a different approach was used in this study. If a greater effort is warranted at a future time, perhaps techniques proposed by Gringorten (1966) using a simple Markov chain process would provide a reasonable compromise between massive input volume and required results.

Our approach makes use of published summaries from which the mean number of precipitation-hours per month as well as the mean number of P.H./P.D. can be computed (U.S. Dep. of Commerce, NOAA 1963). A series of NOAA booklets give a 1951 to 1960 tabulation of hourly observations for individual first-order stations. Ninety comprehensive station booklets are available for the continental United States plus information for Honolulu, Hawaii, and San Juan, Puerto Rico. These provide the basic data used in this study.

STATISTICAL ASPECTS

As stated, the volume of hourly data needed to do an in-depth analysis of precipitation probabilities makes that objective untenable. But even though it necessitates a tedious computational procedure, the frequency curve form for hourly sampled precipitation should be examined; consequently, hand tabulations were carried out for 11 stations over selected months for the years 1952 to 1961. These stations are scattered across the country (table 1); the 2- or 3-month computation for each covers the station's major fire-season. Two sets of stations were selected close together in two States (Oregon and Georgia) to determine if there are major differences in curve form between coastal and inland areas (there were none apparent in these data).

The data were grouped by number of cases of P.H./P.D. The number of occurrences of hourly totals per precipitation-day was then calculated as a percentage of the total number of precipitation-days, resulting in various curve forms, real or apparent (fig. 1). The commonest curve type was evident at seven of the 11 stations: Atlanta, Bandon, Flagstaff, Marquette, Minneapolis, Portland, and Savannah. Here the modal group occurred at a 2 clock-hour precipitation-day. Most curves then either declined with increasing P.H./P.D. (fig. 1, Minneapolis) or declined but then maintained a steady percentage value over a number of groups of precipitation-hours before continuing the decline. In climates or seasons where the "brief shower" is not a normal situation, the tabulation is almost forced to show the 2-hour duration mode. It results from our convention of recording clock-hour precipitation totals. As an example, if there is a 60-minute rain it will be logged as a 2-hour event unless it starts promptly at, say, 8:01 and ends at 9:00.

Another situation occurred at Milwaukee, Albany, Oklahoma City, and Missoula. At these stations 1-hour precipitation-days were most frequent. This is probably the result of brief shower activity, that increases the probability that the precipitation event will be included within a single clock-hour. At Milwaukee there was a percentage decrease until the 3-hour precipitation-day group and then an increase over 4- and 5-hour precipitation-day groups before the major curve decline (fig. 1, Milwaukee). At Albany and Oklahoma City there was a relatively steady percentage decline along the curve. This same curve type occurred with the Missoula data, but the decline was much more pronounced (fig. 1, Missoula). At Missoula, 33 percent of the precipitation-days were contained in 1-hour periods, and a relatively uniform decline occurred along the curve after that.

The tail is another important feature of these curves. The longest precipitation period occurred at Marquette--over the entire 24 hours. The 10 other stations had at least 1 day with 16 to 23 hours of precipitation over the examined time period. The time defining a precipitation-day is rigid--midnight to midnight. Consequently, the computational method used here inflates the number of daily precipitation events and thus underestimates tail length. This distortion is not too important in some regions during spring and summer months because thunderstorm activity tends to be a late afternoon and early evening phenomenon ending within the defined hours of the precipitation-day. For longer lasting precipitation events, however, the period carries into the

Table 1.--*Eleven-station comparison of base data, means, percentile levels, and gamma-beta parameter values*

(1) Station	(2) Range of months tabulated (1952 to 1961)	(3) Number of precipitation-days in 10-yr. tabulation period	(4) Mean of P.H./P.D.	(5) Percentile level of values in column (4)	(6) Median or number of P.H./P.D. at 50th-percentile level	(7) Column (4) minus column (6)	(8) Gamma distribution parameter estimates: Gamma	(9) Gamma distribution parameter estimates: Beta
		Days	*Hours*		*Hours*	*Hours*		
Albany, N.Y.	April-May	280	5.2	63	3.7	1.5	1.36	3.81
Atlanta, Ga.	Feb.-April	307	5.6	65	4.0	1.6	1.67	3.38
Bandon, Ore.	July-Aug.	51	4.1	67	2.8	1.3	1.86	2.22
Flagstaff, Ariz.	April-June	109	4.9	65	3.5	1.4	1.74	2.81
Marquette, Mich.	April-May	241	5.6	64	4.0	1.6	1.27	4.38
Milwaukee, Wis.	April-May	225	4.4	63	3.2	1.2	1.81	2.50
Minneapolis, Minn.	April-May	185	5.2	62	3.8	1.4	1.48	3.57
Missoula, Mont.	July-Sept.	198	3.1	63	2.2	0.9	1.34	2.31
Oklahoma City, Okla.	March-April	160	4.2	63	3.1	1.1	1.80	2.42
Portland, Ore.	July-Aug.	71	4.6	65	3.3	1.3	1.92	2.41
Savannah, Ga.	Feb.-April	255	4.7	62	3.6	1.1	1.72	2.92
Eleven-station average	--	--	4.7	65	3.3	1.3	--	--

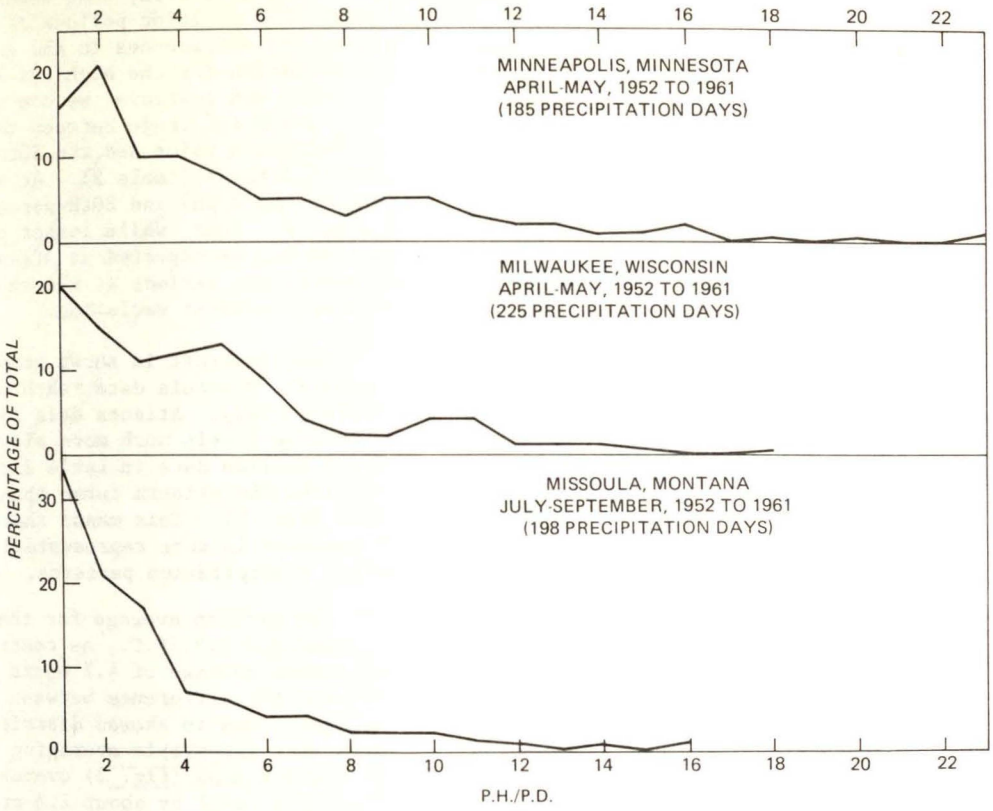

Figure 1.--*Three distributions showing the occurrence of average hours of precipitation per precipitation-day. Distributions are presented as a percentage of the total number of precipitation-days.*

following day. This fact also accounts, in part, for the variation in the skewness factor that shows up in some of the computed distributions (fig. 1).

Changnon and Huff (1967), among others, have attempted to bypass some of the problems inherent in studies of precipitation duration by using a "6-hour definition." They define a storm as a precipitation period separated from preceding and succeeding precipitation by 6 hours or more. Shenton and Skees (1970) have expanded this concept by analyzing for eight "storm definitions"--letting dry periods vary from 1 to 8 hours between precipitation and redefining the concept of a storm dependent upon dry period length. Their work on distribution of storm durations shows that in the Southeast about three-fourths of the storms are over within 3 hours if the criterion is 1 dry hour between storms. Almost nine out of 10 storms are over within 6 hours using the same 1 dry-hour criterion. Their data also indicate there is a fair percentage of precipitation carryover into a following calendar day if a rigid definition of day is used and if one assumes random precipitation with respect to time of day.

Because of the discussed restrictions of the basic data tabulated for this study, alternate methods of defining precipitation duration could not be used. Also, problems could develop in using alternative tabulation methods because solutions obtained might not apply to operational systems such as the NFDRS. Information must be definable within the restrictions of a given system if it is to be usable, and operational systems usually specify a rigid time period for input data.

Because of the shape of the frequency distributions (fig. 1), few of the classical distributions appear suitable to describe these precipitation data. Shenton and Skees (1970) feel that this may be due to the J-shaped distribution feature. Mode is at either the 1- or 2-hour distribution group. A study they conducted shows that this factor rules out a number of possible functions. They did find that a modified-logarithmic distribution often produces a good fit, although this statistical form depends upon one parameter and consequently lacks flexibility.

Results obtained with a fit of the gamma probability function are explored here because it

is a two-parameter frequency distribution; a fit of this function yields both scale and shape. Reliability tests performed on these data showed that the goodness-of-fit was much better with it than with other tested functions. As shown by Thom (1958), the gamma probability function is given by the equation:

$$f(x) = \frac{1}{\beta^{\gamma}\Gamma(\gamma)} x^{\gamma-1} e^{-x/\beta}, \text{ where } \beta>0 \text{ and } \gamma>0.$$

Here x is the random variable, β is the scale parameter, γ is the shape parameter, and Γ is the usual gamma function. The shape parameter, gamma, is inversely related to the skewness of a frequency distribution. That is, a smaller gamma indicates that a few large values cause positive skewness and that the mean departs further from the median value. A large gamma causes the probability function to approach normality. Beta, the scale parameter, indicates range or dispersion. A larger beta indicates a greater tendency to deviate from either the mean or the median. β and γ are inversely related by the function $\beta = \bar{x}/\gamma$, where $\bar{x}$ is the mean. Therefore $\gamma\beta = \bar{x}$ and $\gamma\beta^2 = \sigma^2$.

Barger *et al.* (1959), Feyerherm *et al.* (1966), Strommen and Horsfield (1969), and others have shown that the gamma probability function presents a practical application for precipitation in a climatological data series. The features can be illustrated by contrasting data at Missoula and Atlanta (table 1, columns 4 and 6). These latter data were computed from frequency tabulations after fitting the gamma function.

At Missoula the 50th-percentile value is 2.2 P.H./P.D. At Atlanta the value is 4.0. This indicates, of course, that usually there are longer precipitation periods at Atlanta. By comparing the differences in the expected hours of precipitation for the high and low probabilities for these two stations, we can assess variability. At Missoula the range between the 20th-percentile precipitation value and the 80th-percentile is about 4.0 hours (table 2). At Atlanta the range between the 20th- and 80th-percentile levels is 6.3 hours. Thus, while longer precipitation periods can be expected at Atlanta relative to Missoula, the periods at the eastern location show much greater variation.

This contrast is shown graphically in figure 2. Missoula data reach high-percentile levels rapidly. Atlanta data reach high-percentile levels much more slowly. Averaging of all station data in table 2 produces a curve more like the Atlanta curve than the Missoula curve (fig. 2). This means that the sample of 11 stations is more representative of longer period precipitation patterns.

The station average for the 50th-percentile is about 3.3 P.H./P.D., as contrasted with the arithmetic average of 4.7 hours (table 1). This reflects the difference between the median and the mean found in skewed distributions. It indicates that the simple averaging used to produce the monthly maps (fig. 3) overestimates the 50th-percentile level by about 1.4 precipitation-hours during major fire-seasons. Simple averaging produces a value at about the 65th-percentile level. Both this situation and the clock-hour recording procedure previously discussed produce a bias. *Therefore, when using these data maps during the fire season, one should subtract about 1-1/2 hours from the map values to arrive at actual values.* During snow seasons the difference value will probably be even higher.

Table 2.--*Cumulative percentage frequencies of precipitation-hours/precipitation-day at 11 stations*
(In P.H./P.D.)

Station	Percentile level							
	20	30	40	50	60	70	80	90
Albany, N.Y.	1.4	2.1	2.8	3.7	4.8	6.2	8.0	10.8
Atlanta, Ga.	1.5	2.3	3.1	4.0	5.0	6.4	7.8	10.7
Bandon, Ore.	1.2	1.7	2.2	2.8	3.6	4.2	4.8	5.5
Flagstaff, Ariz.	1.3	2.0	2.8	3.5	4.5	5.5	7.0	8.2
Marquette, Mich.	1.4	2.1	3.0	4.0	5.0	6.5	8.5	11.2
Milwaukee, Wis.	1.3	1.8	2.5	3.2	4.1	5.1	6.5	8.8
Minneapolis, Minn.	1.5	2.2	2.9	3.8	4.9	6.2	8.0	11.6
Missoula, Mont.	<1.0	1.2	1.7	2.2	2.8	3.7	4.9	6.8
Oklahoma City, Okla.	1.2	1.8	2.4	3.1	4.0	4.9	6.2	10.0
Portland, Ore.	1.3	1.9	2.6	3.3	4.1	5.2	6.3	7.2
Savannah, Ga.	1.4	2.1	2.8	3.6	4.5	5.6	7.2	9.6
Average	1.2	1.9	2.6	3.3	4.3	5.4	6.8	9.1

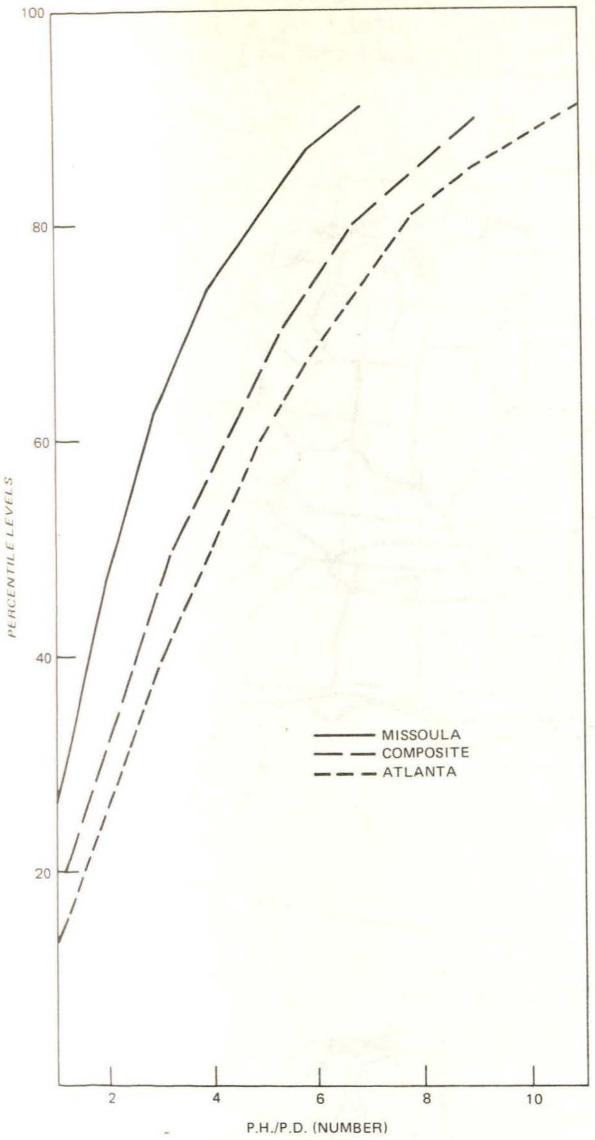

Figure 2.--*Cumulative percentage frequencies of hourly precipitation-day groups at two stations and the 11-station composite.*

PATTERNS OF HOURLY PRECIPITATION

Isolines are drawn for all mapped data east of the Rocky Mountains (figs. 3 and 4). The procedure is questionable west of the 105° W. meridian due to a combination of sparse data and mountainous terrain. Therefore, western-region values were plotted on the maps at the site of precipitation observations with no attempt to draw constant-value lines.

The annual plot of precipitation-hours (fig. 4A) shows similar patterns to those produced by the U.S. Dep. of Commerce, NOAA's (1968) maps of "mean number of days with 0.01 inch or more of precipitation." Highest hourly concentrations are in the New England States and the Pacific Northwest. The lowest are in the Southwest. The winter months (December, January, and February) furnish the major portion of this total in the New England States. The Pacific Northwest includes this same time period as well as late fall and early spring in its major concentration of hourly means. Greatest extremes are experienced in southern California, where an average of about 50 hours of precipitation during January changes to few or no hours from June through September.

The charts of mean P.H./P.D. do not always conform to the same patterns as the previous set of charts. (Discussed values of P.H./P.D. are the plotted-map values, although, as stated, map values are more than 1 hour greater than 50th-percentile values.) Although high-annual figures (fig. 3, annual) predominate in the New England States, much of the trend across the country as seen in the other annual chart (fig. 4, annual) is not well delineated. On an annual basis the vast majority of stations average out between 4 and 5 P.H./P.D. There is, however, considerable variation over the country from month to month.

Highest values are recorded along the Northeastern-Coastal region and isolated portions of the far Northwest. This is mostly a winter and early spring snow-shower phenomenon, with values of over 7 P.H./P.D. at this time. The shortest precipitation intervals occurred throughout California during July--1.0 P.H./P.D. (fig. 3, July). However, these means should be viewed with caution. The previous set of map data showed that less than 5 hours of rain fell in California during the 10 July periods covered. The small data base will not produce a meaningful statistic.

The most obvious application of these data is as climatological input to the NFDRS when "real-time" information is not available. As an example, if one only knows that rain has fallen at Minneapolis on a given day in March but does not know the precipitation-time intervals, they could be estimated with the P.H./P.D. March chart. That map shows the 5.0 P.H./P.D. line passing near Minneapolis. Subtracting 1-1/2 hours to compensate for recording and computational bias gives a value of 3.5 precipitation-hours for the given March precipitation-day at that station.

Figure 3.--*Mean annual and monthly maps of precipitation-hours per precipitation-day (based on period from 1951 to 1960). The highest and lowest mean values are shown within the analyzed area so gradients might be more easily identified.*

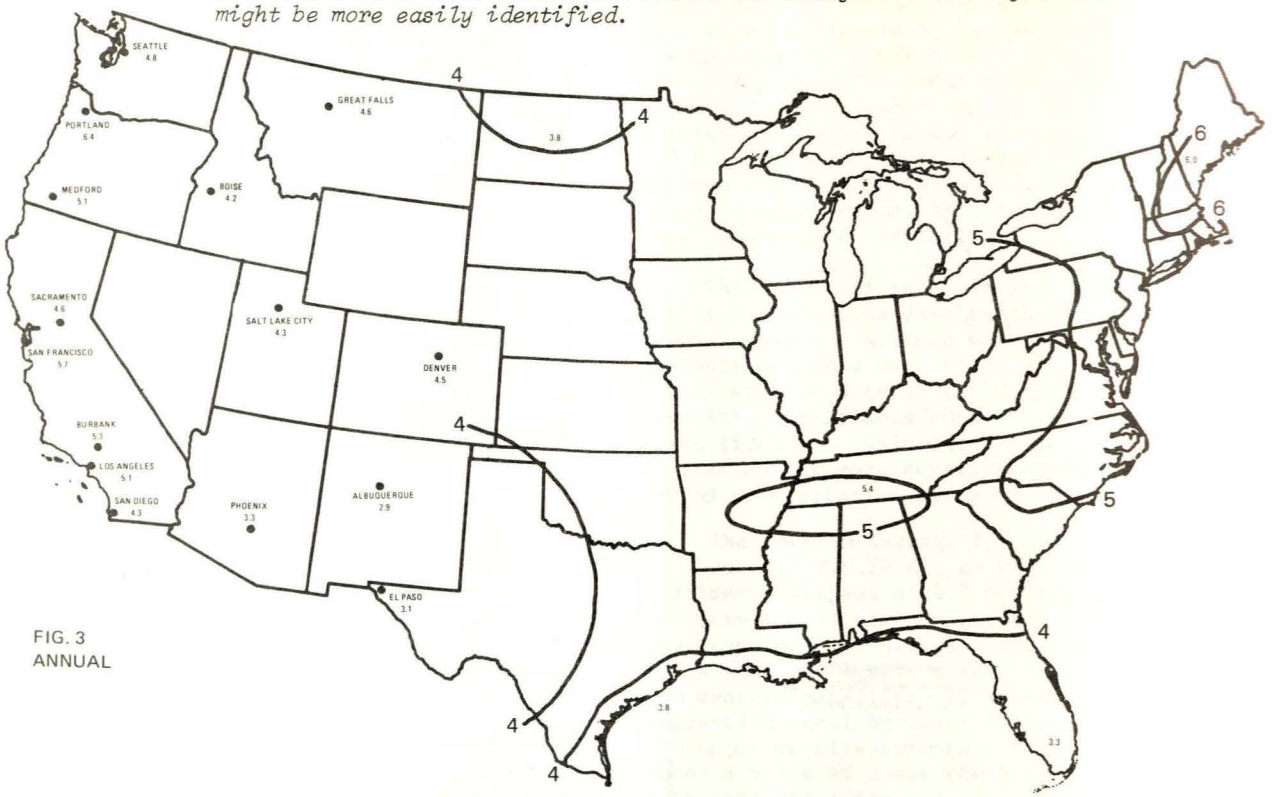

FIG. 3
ANNUAL

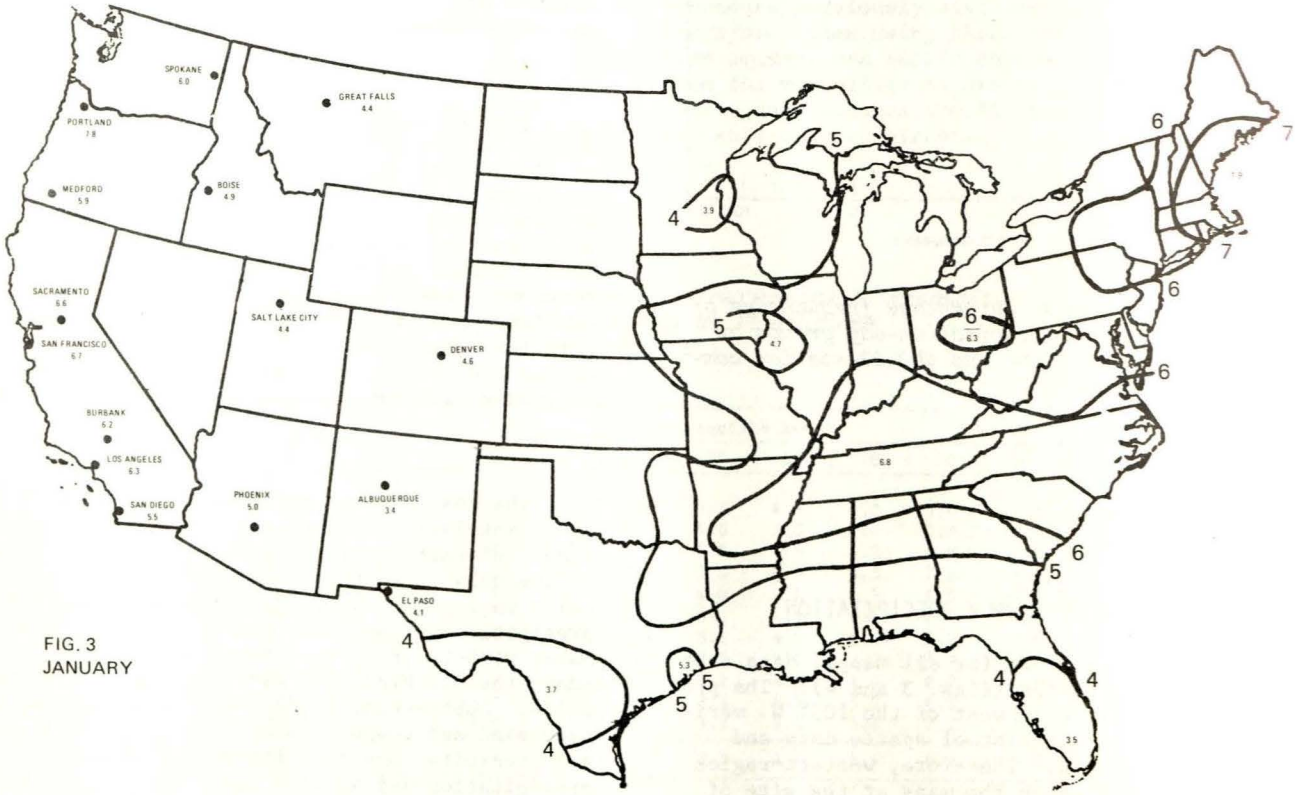

FIG. 3
JANUARY

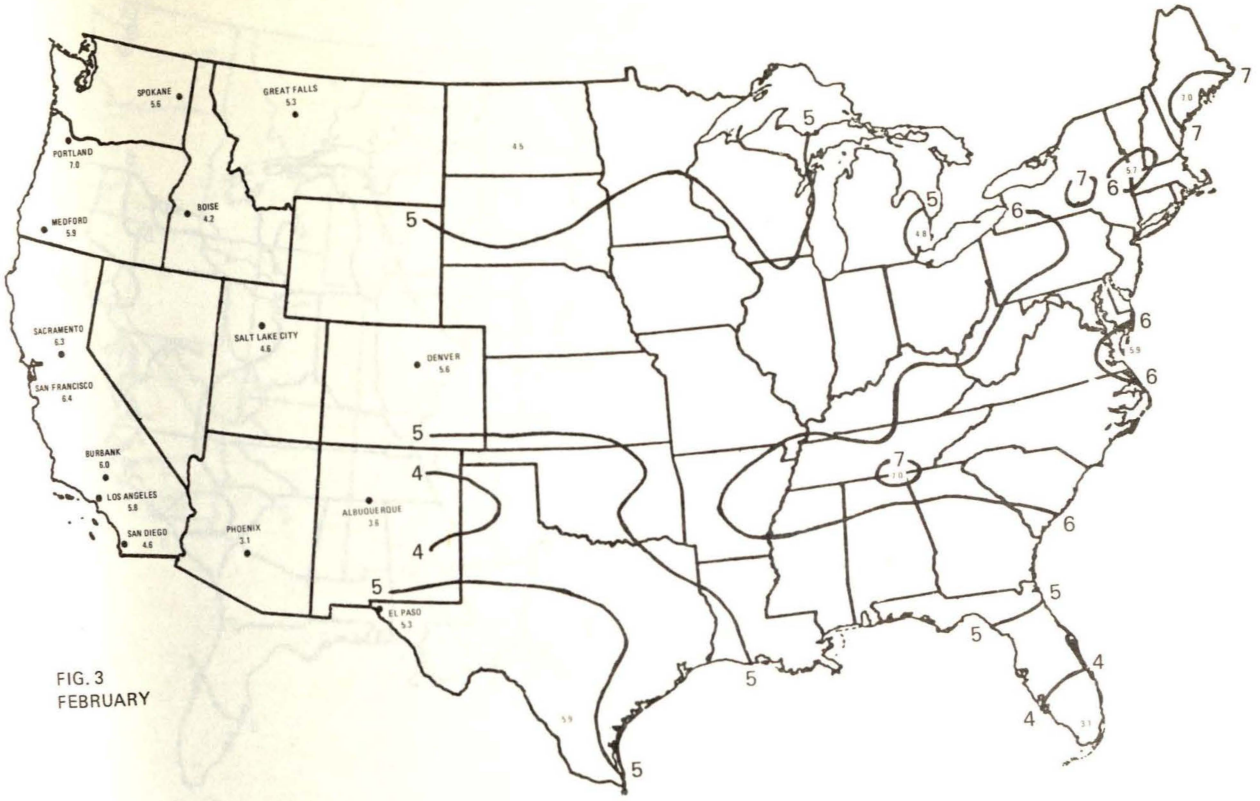

FIG. 3
FEBRUARY

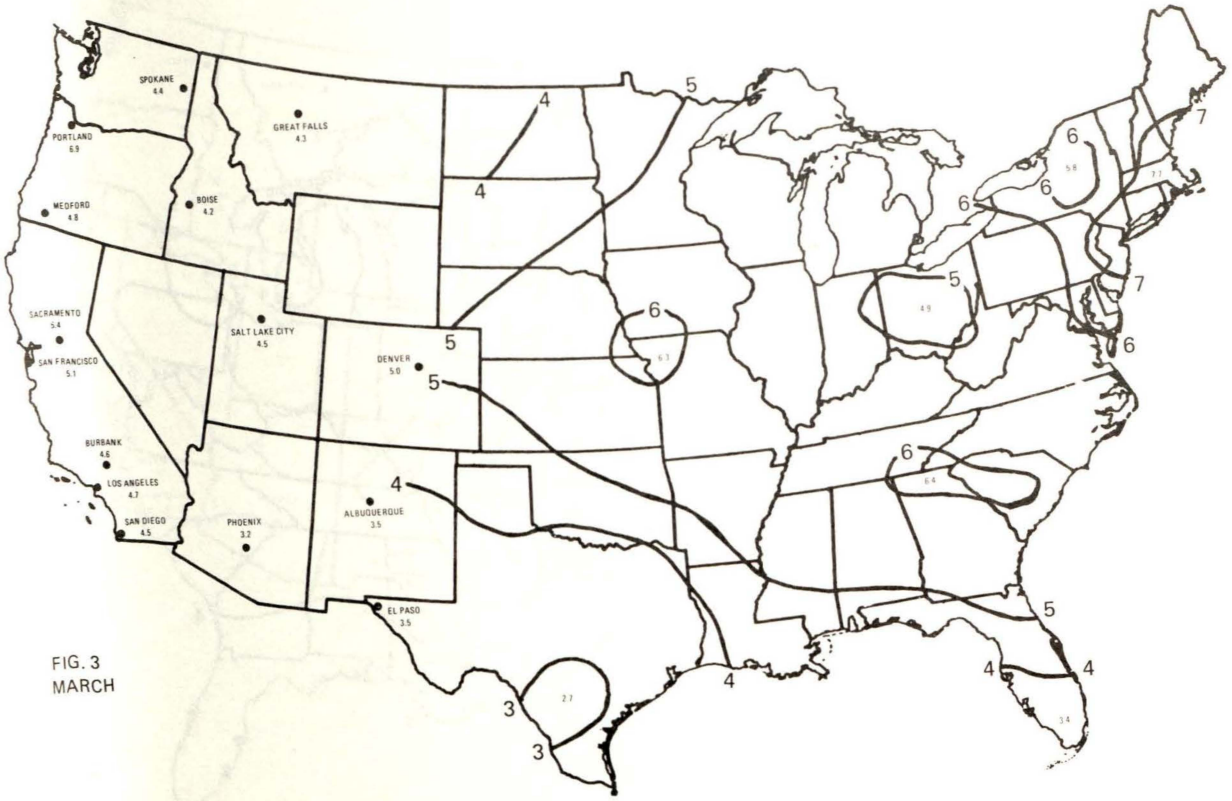

FIG. 3
MARCH

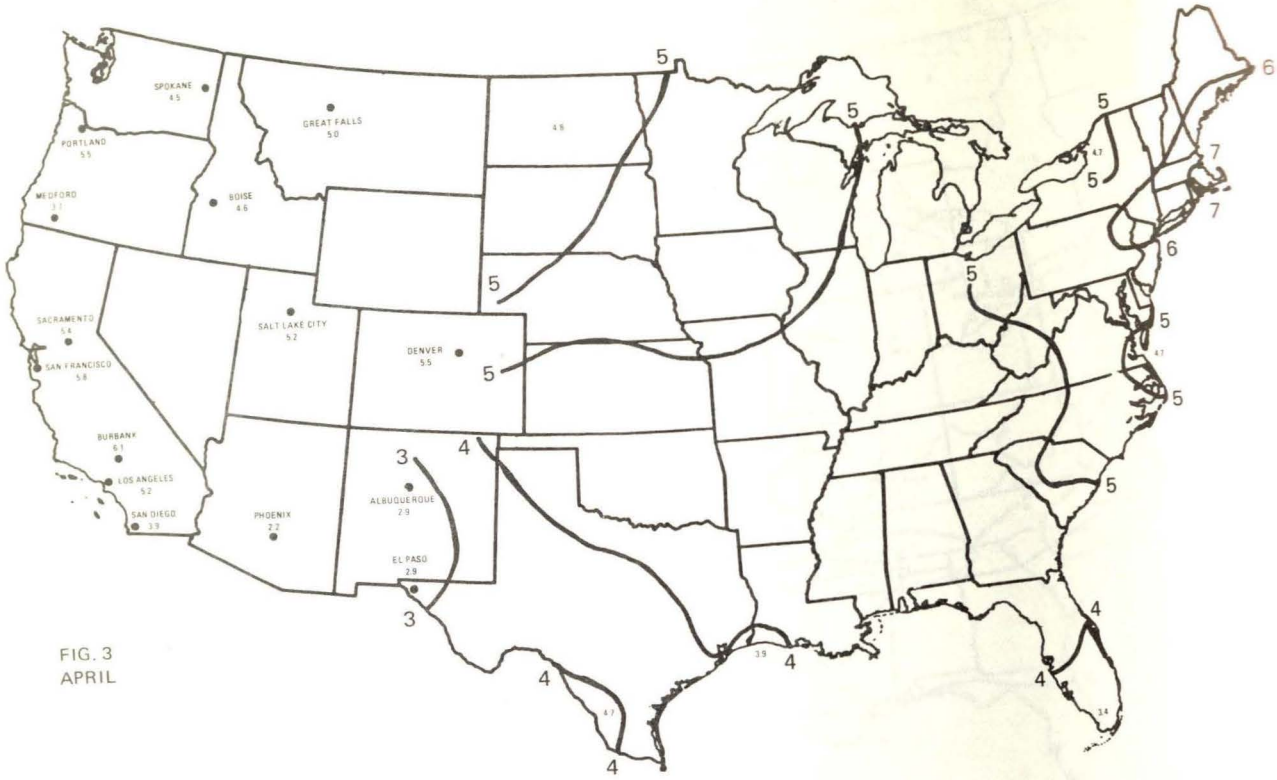

FIG. 3
APRIL

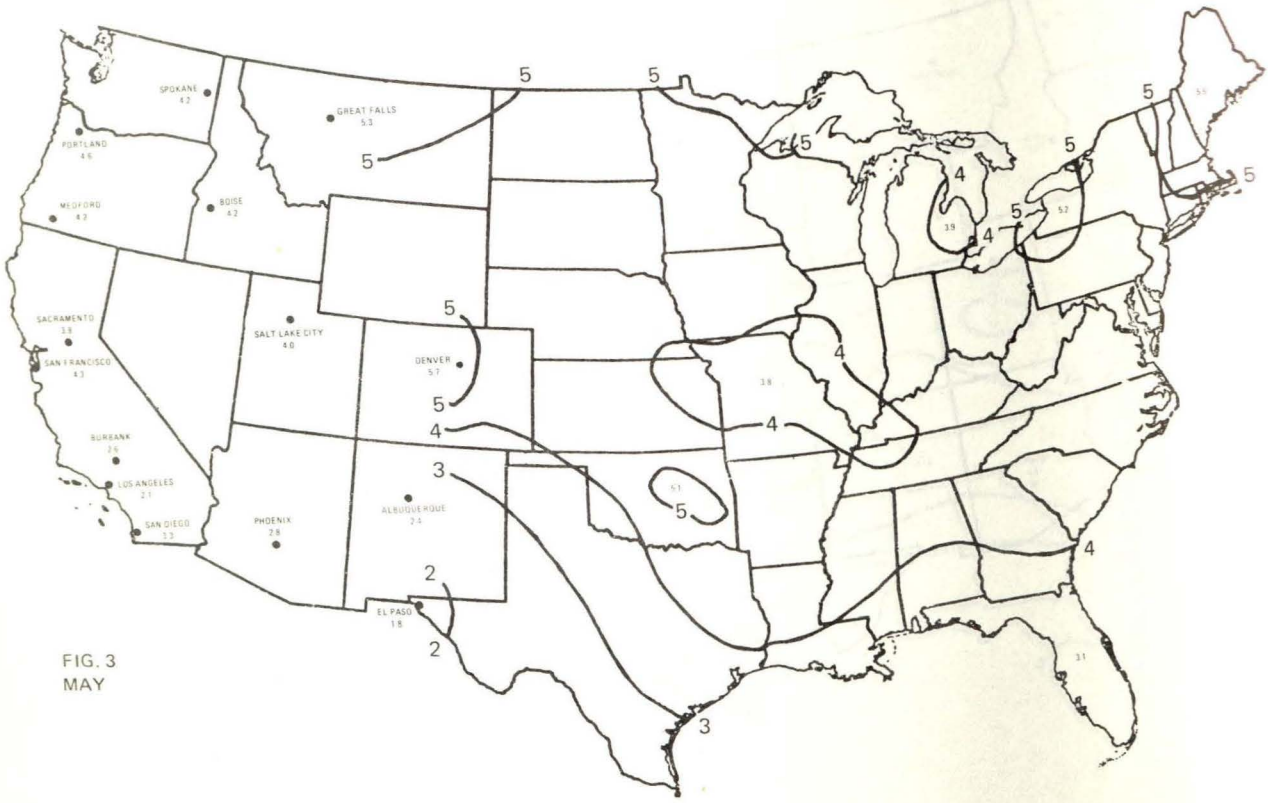

FIG. 3
MAY

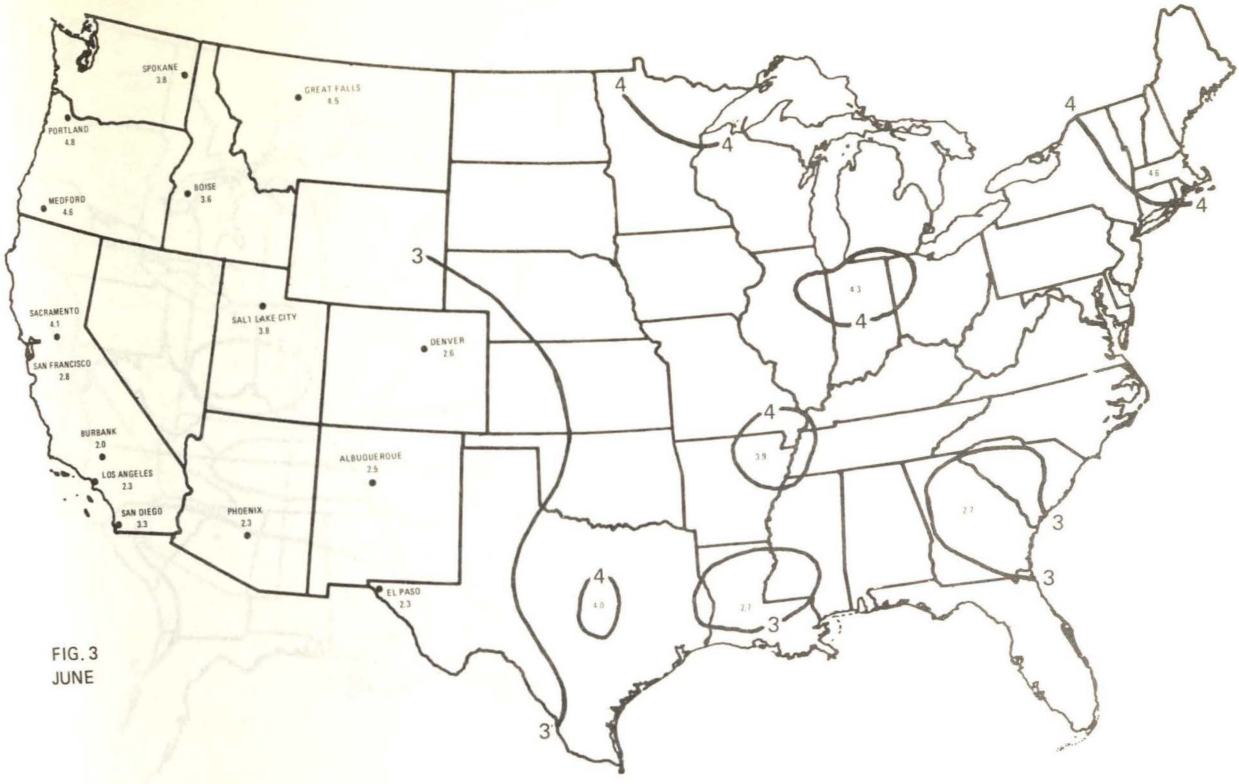

FIG. 3
JUNE

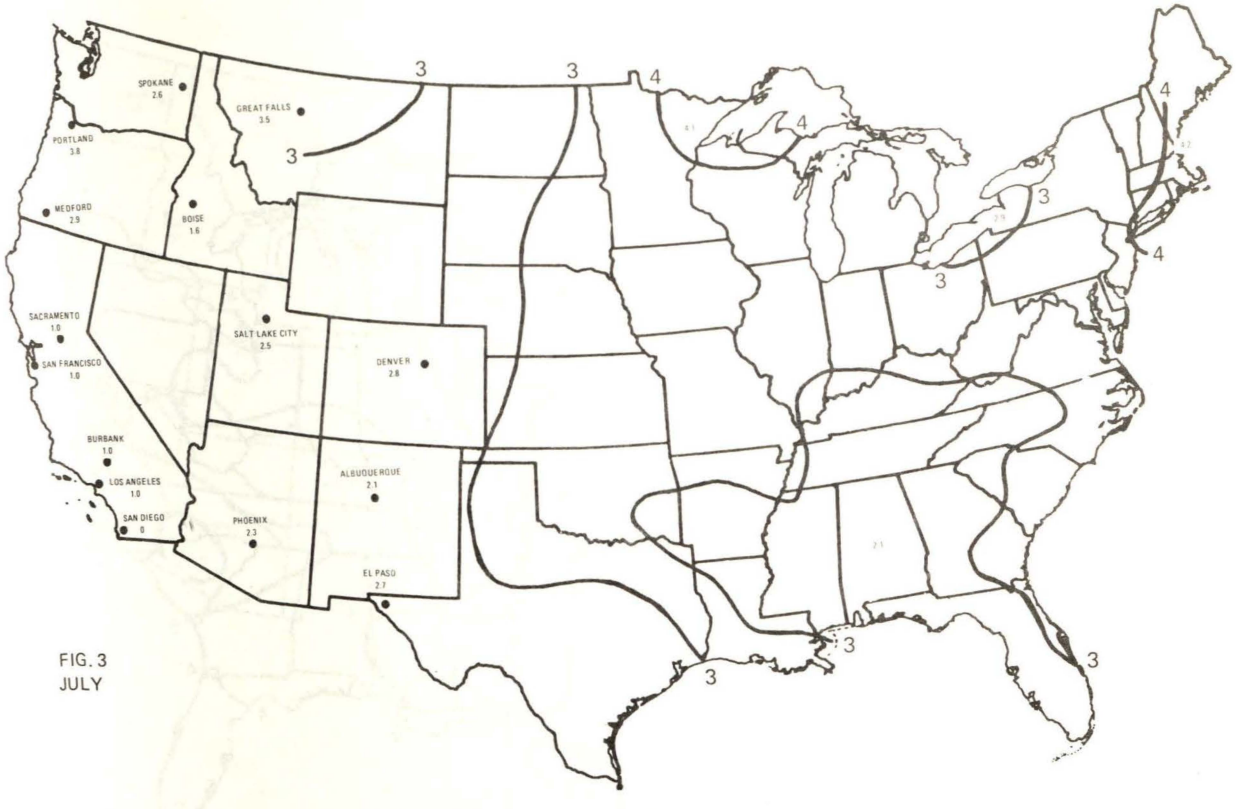

FIG. 3
JULY

FIG. 3
AUGUST

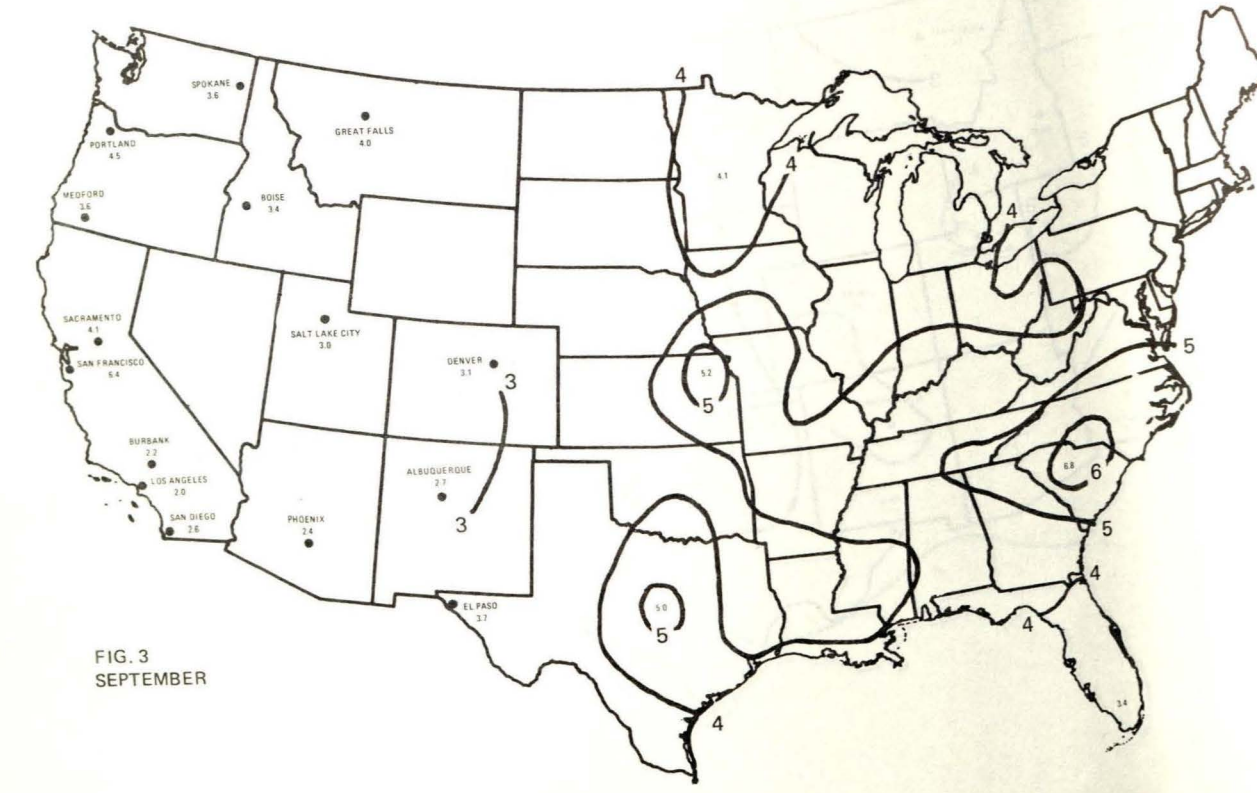

FIG. 3
SEPTEMBER

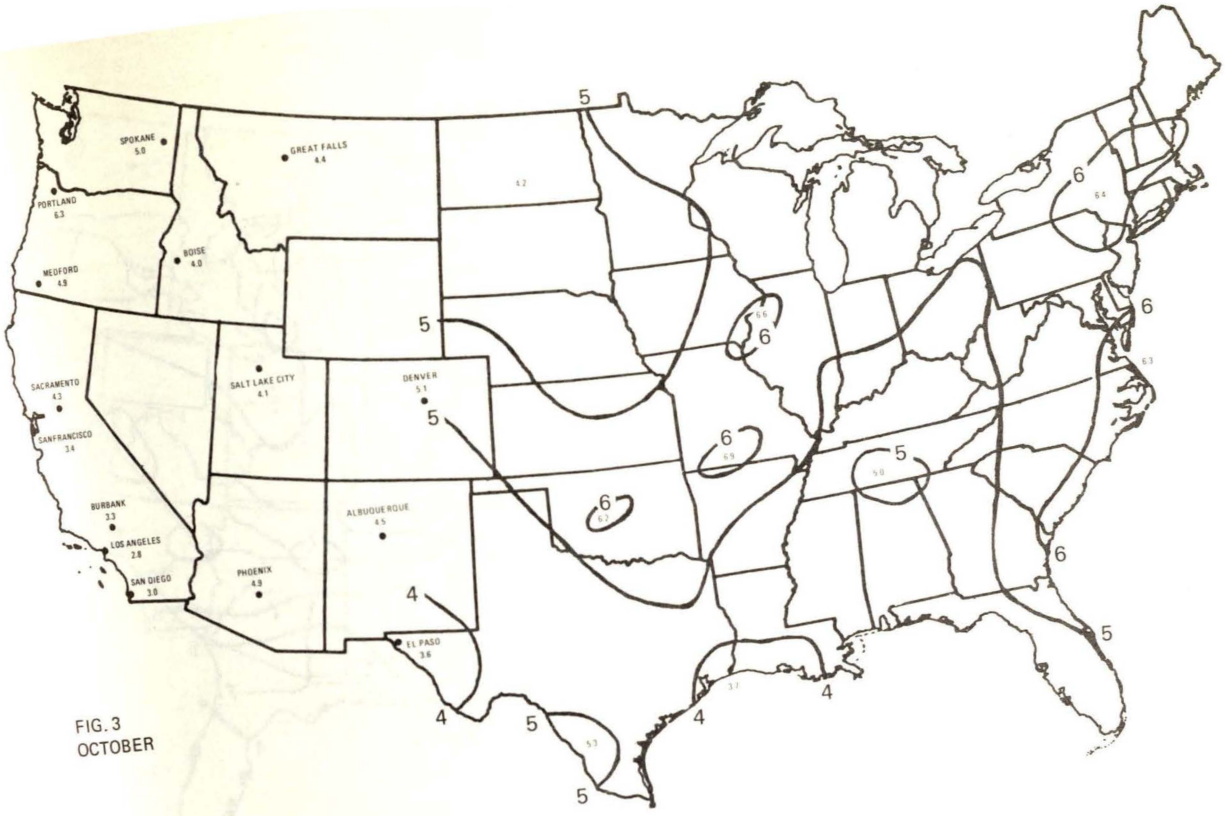

FIG. 3
OCTOBER

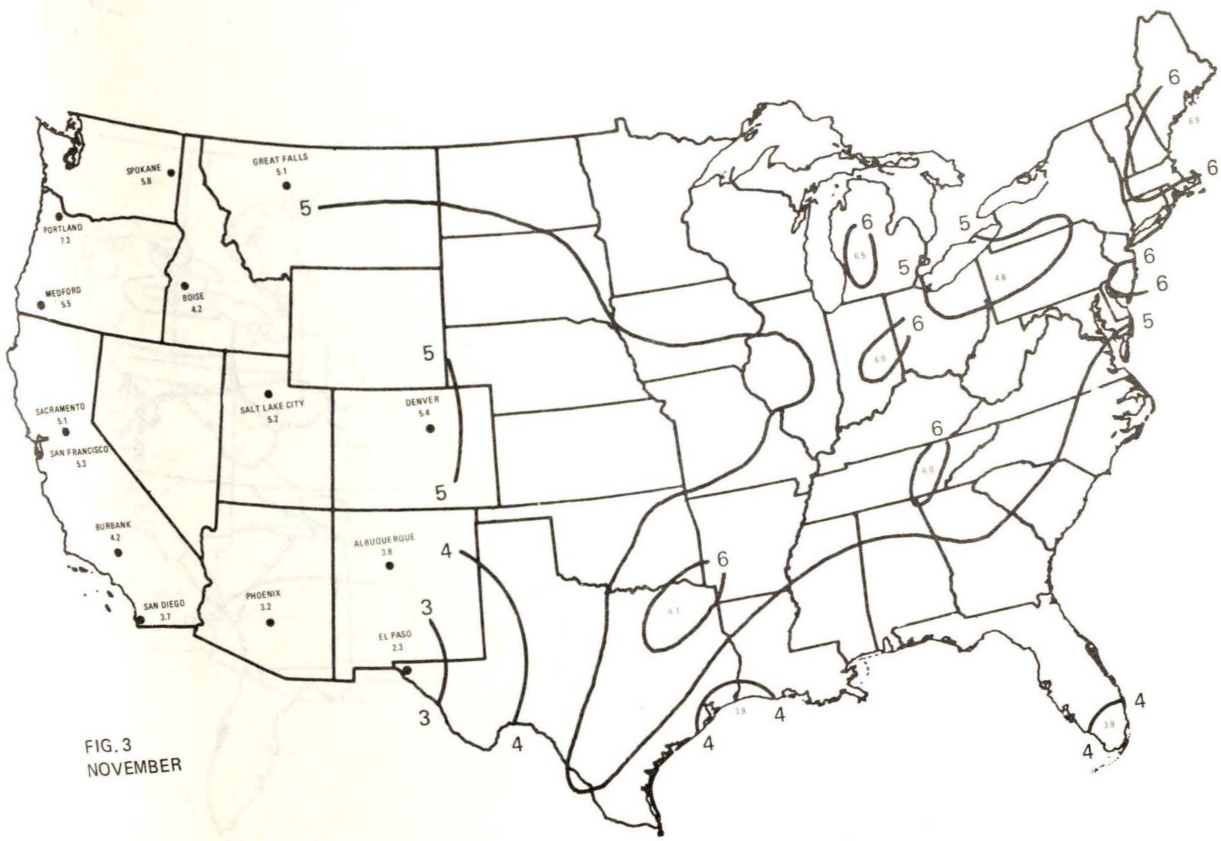

FIG. 3
NOVEMBER

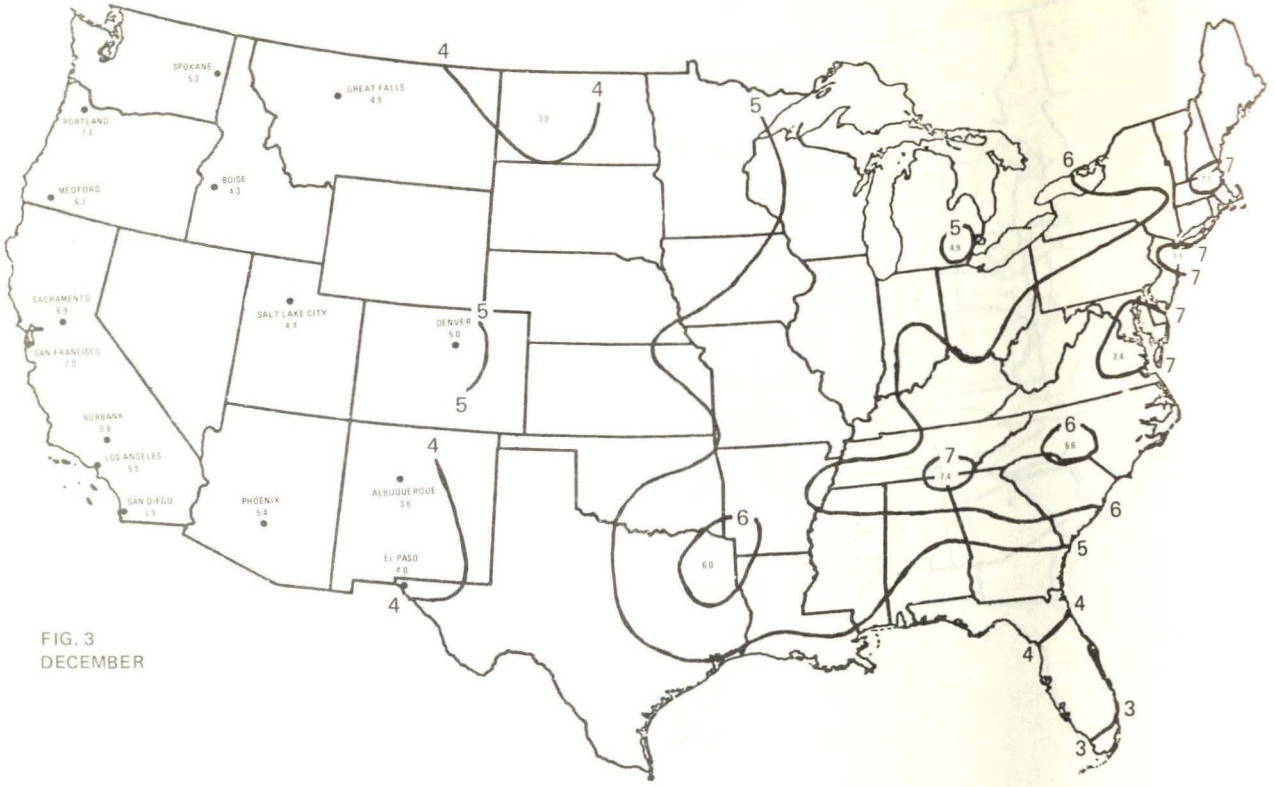

FIG. 3
DECEMBER

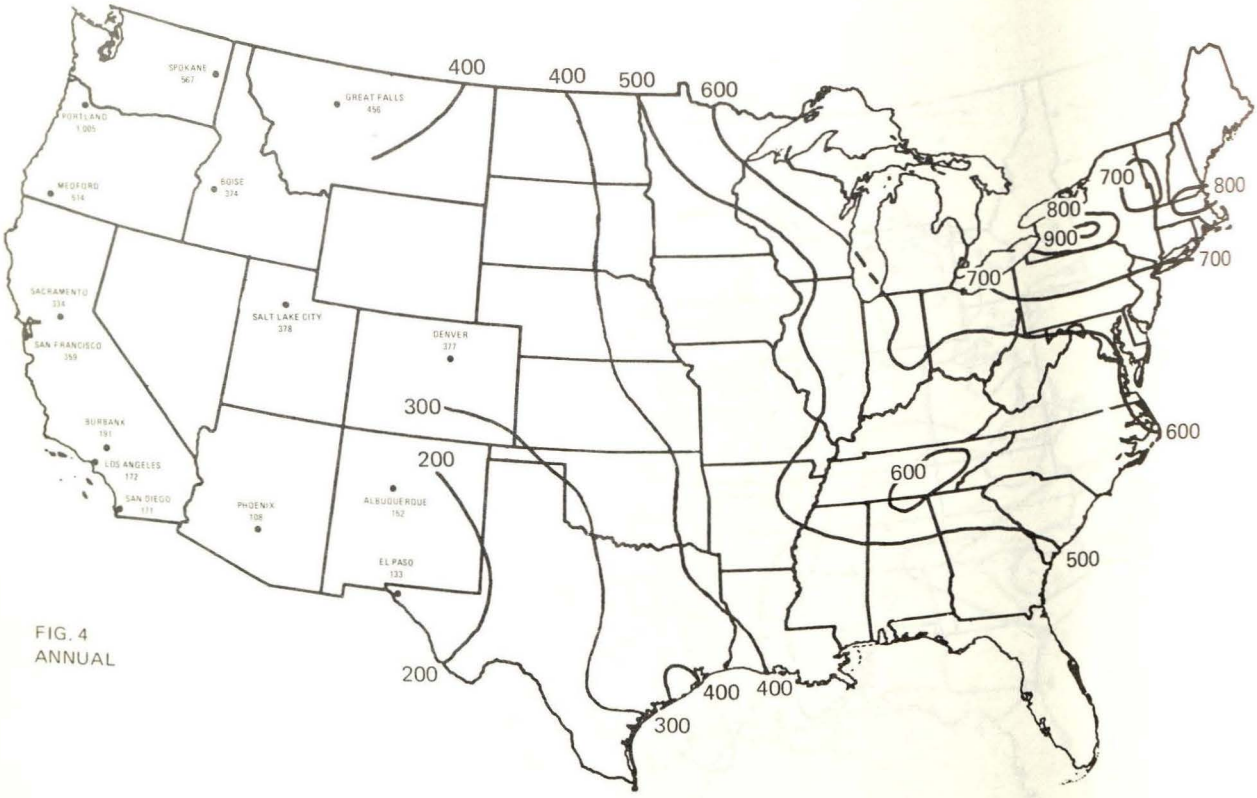

FIG. 4
ANNUAL

Figure 4.--*Mean annual and monthly maps of number of hours with precipitation (based on period from 1951 to 1960).*

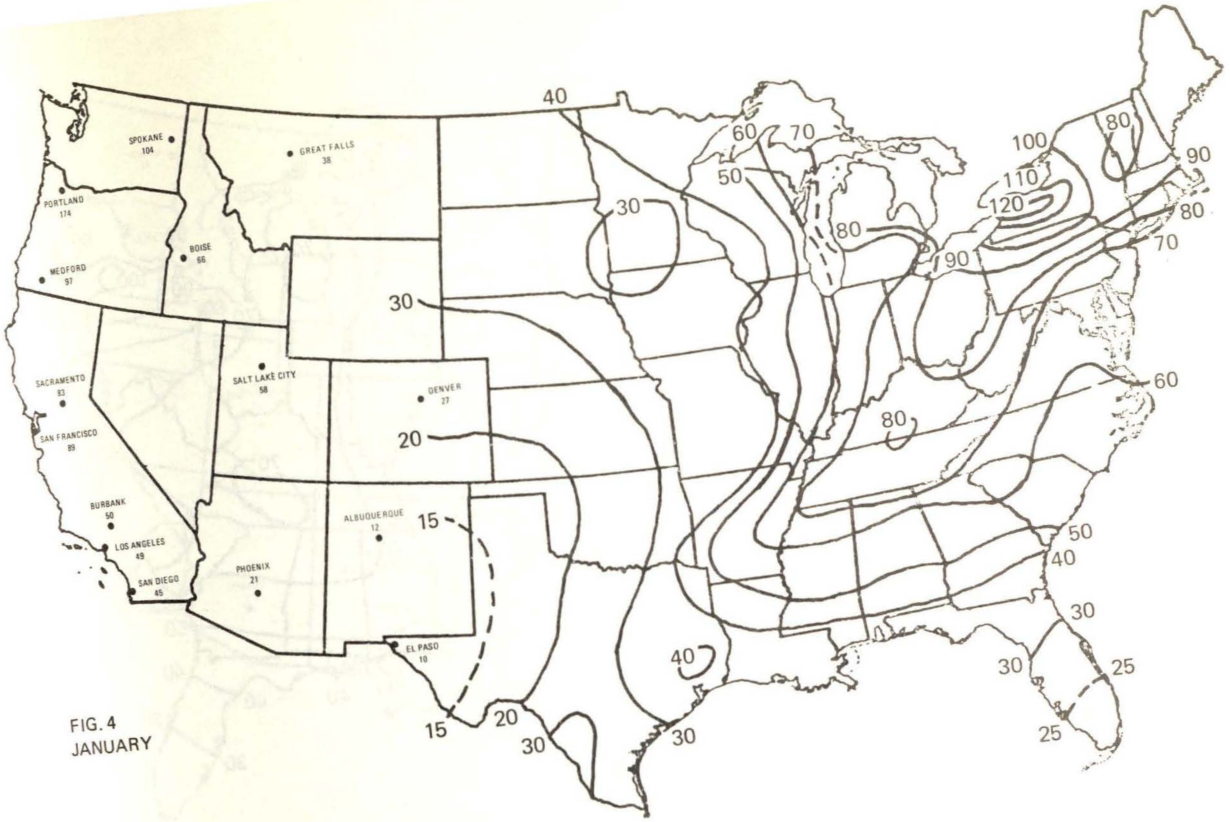

FIG. 4
JANUARY

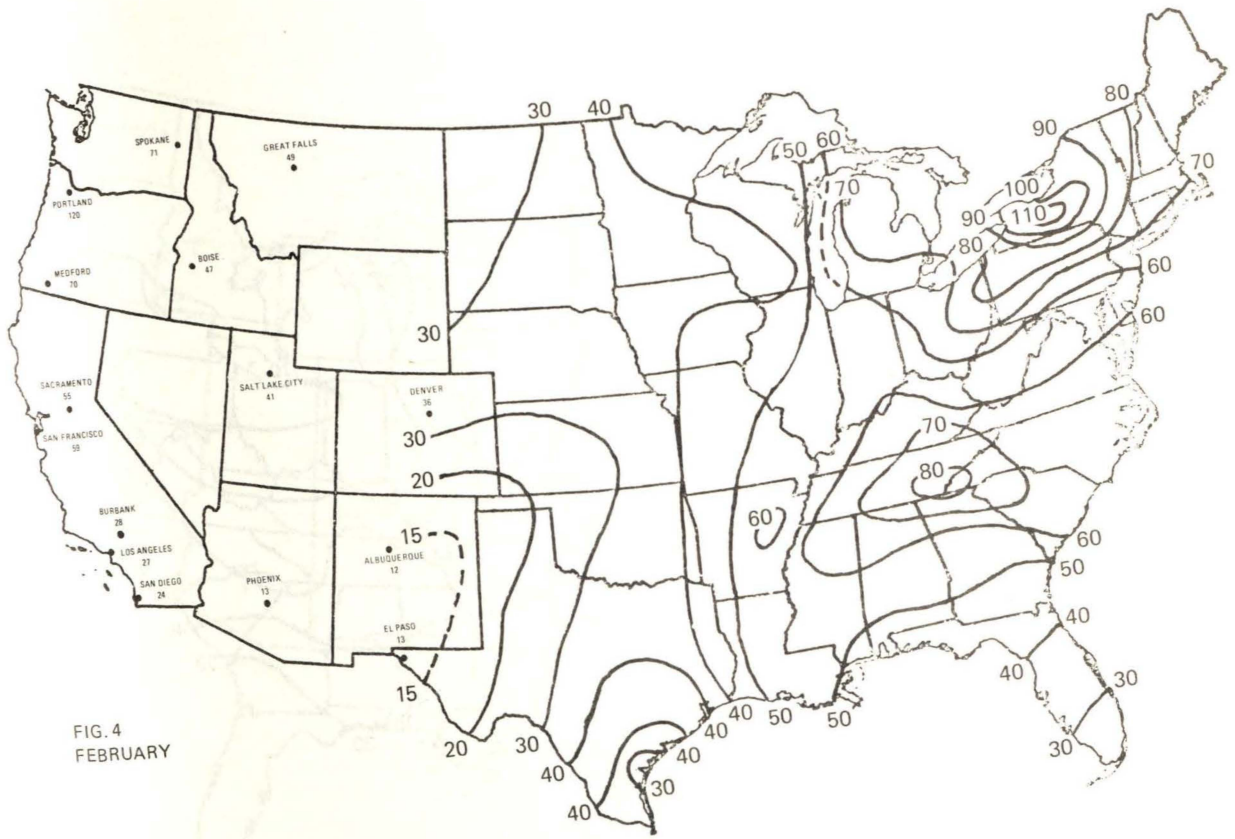

FIG. 4
FEBRUARY

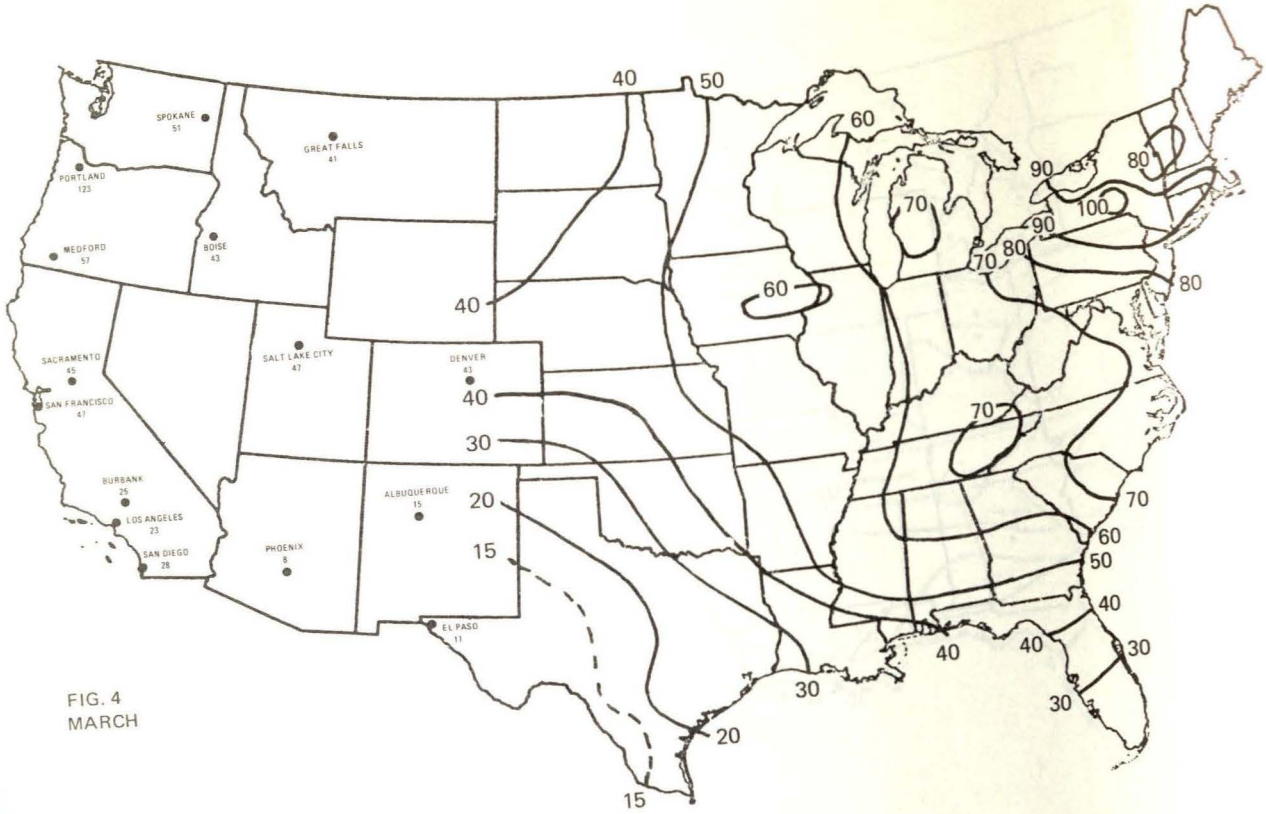

FIG. 4
MARCH

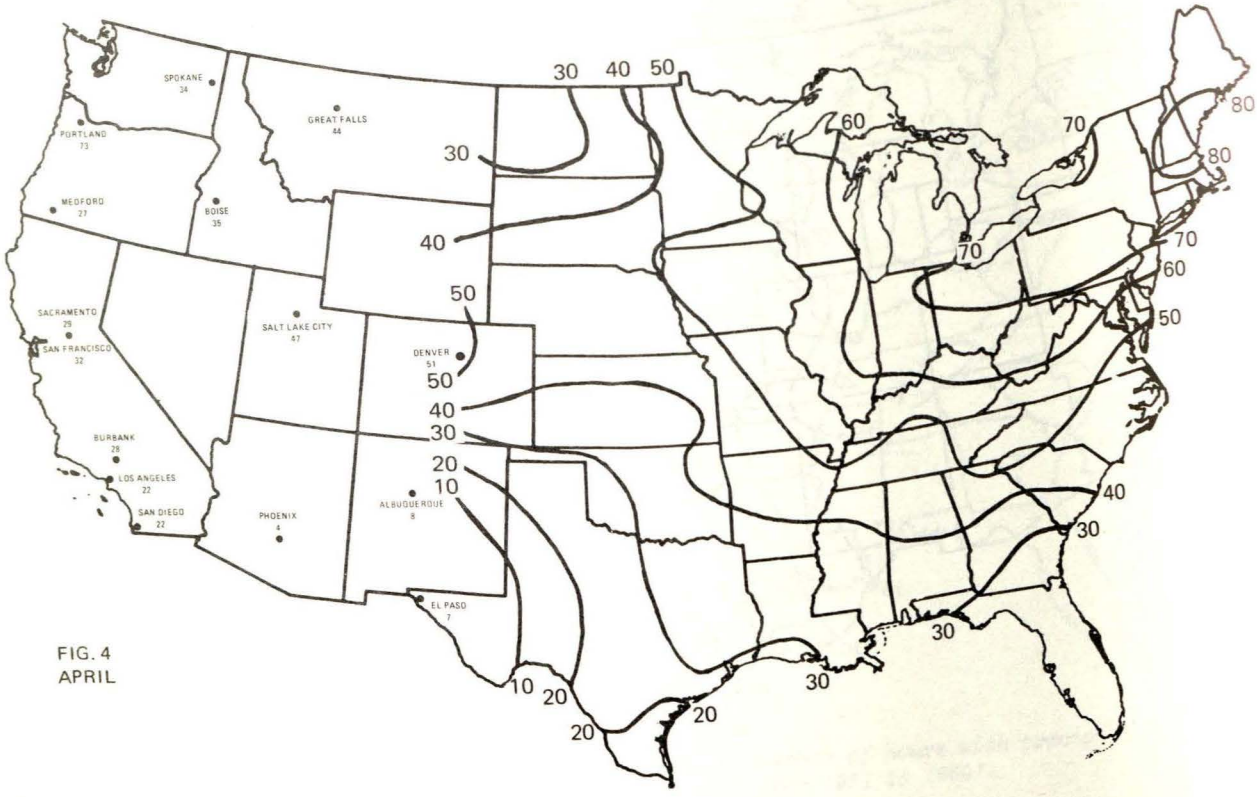

FIG. 4
APRIL

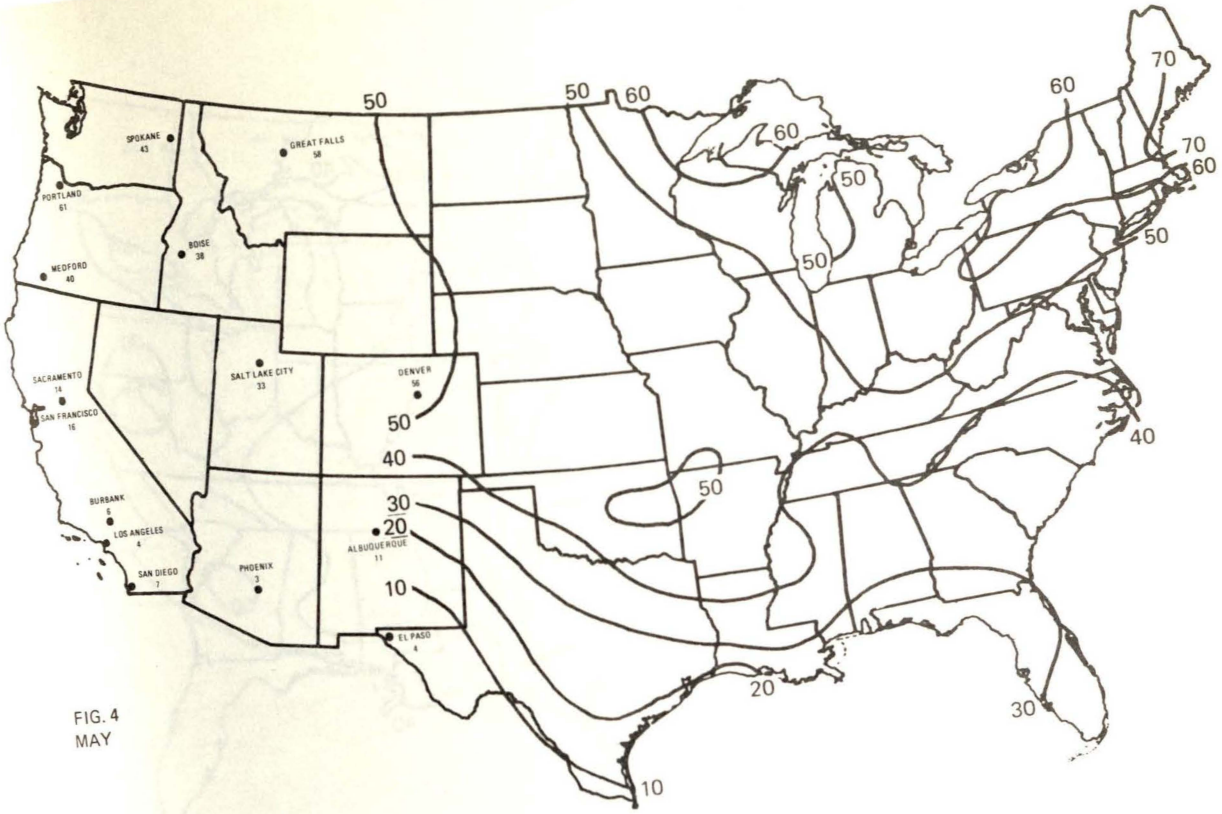

FIG. 4
MAY

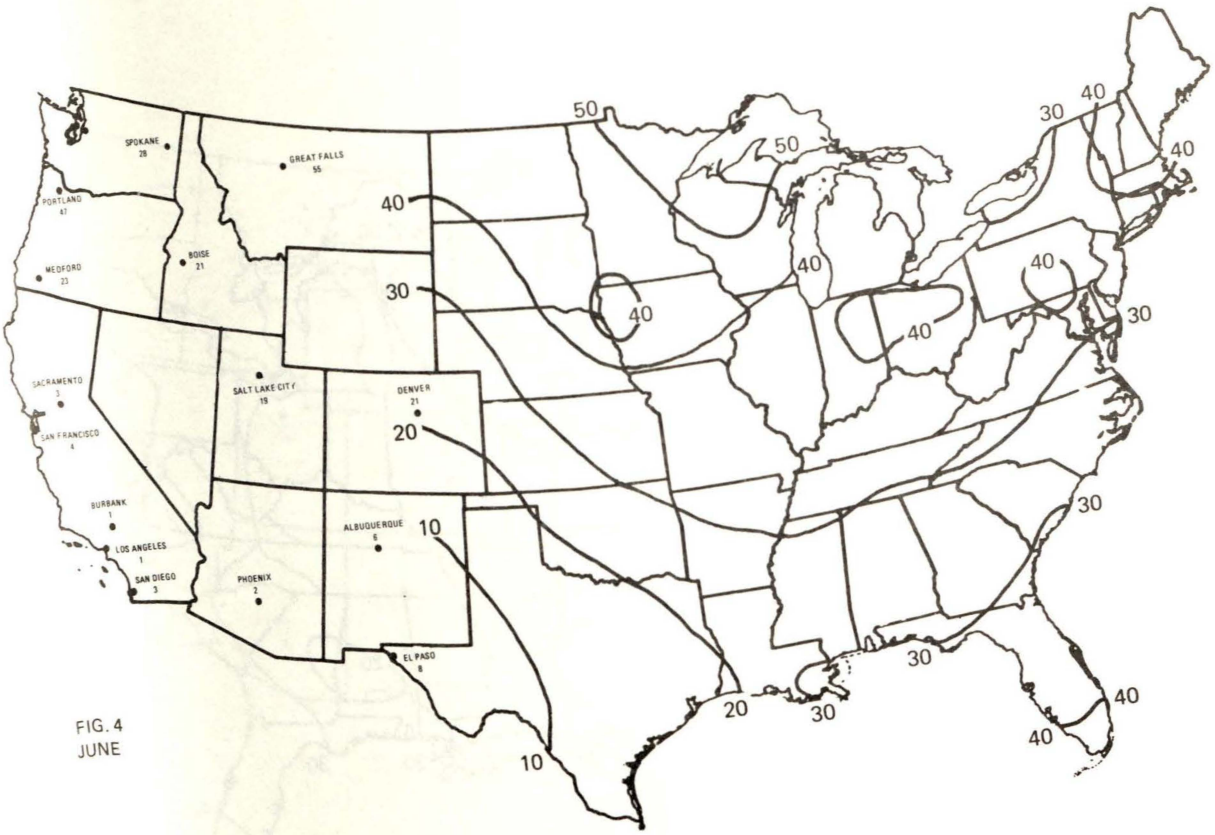

FIG. 4
JUNE

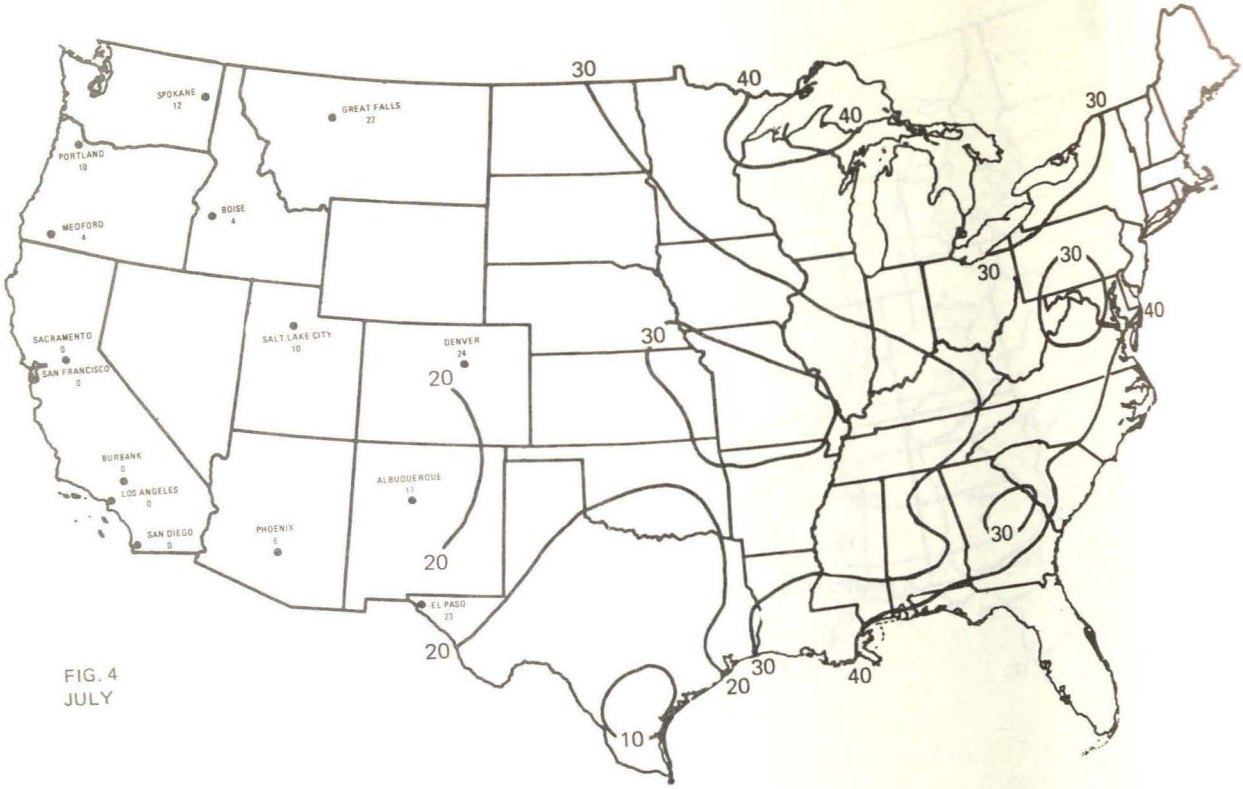

FIG. 4
JULY

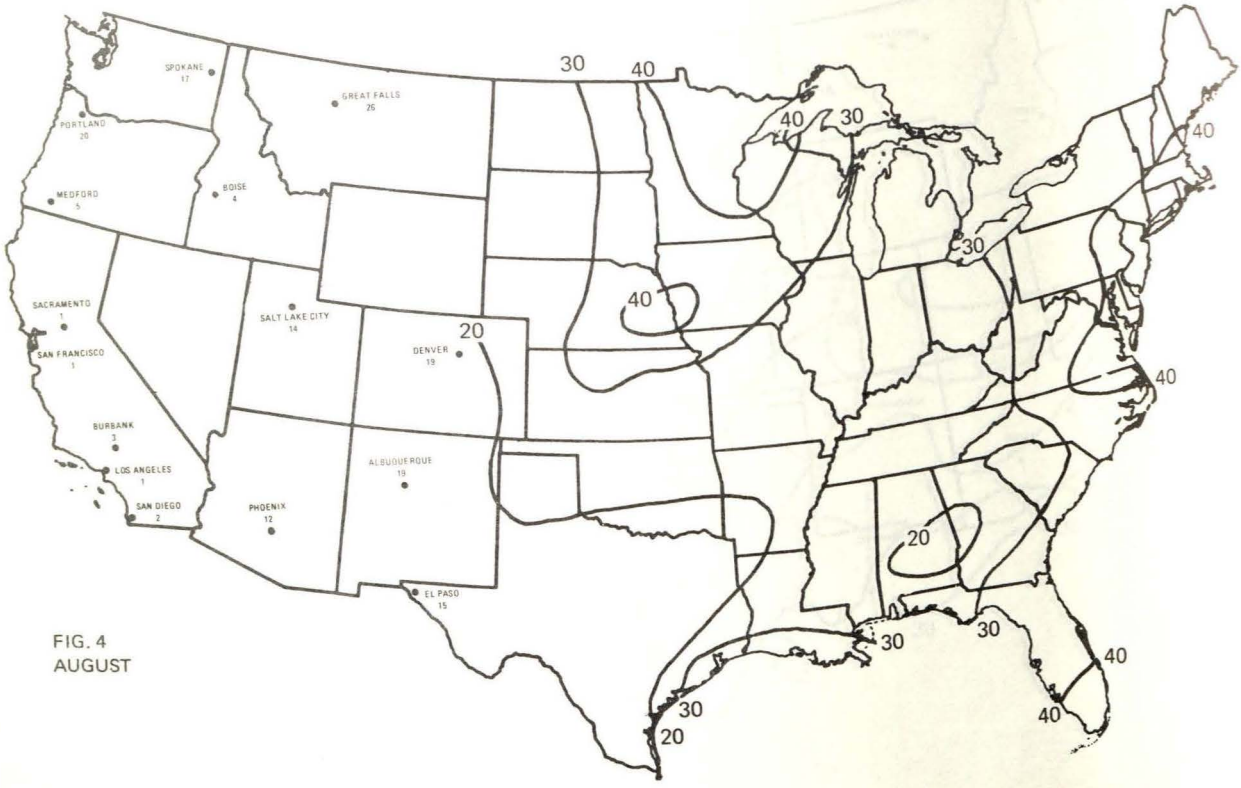

FIG. 4
AUGUST

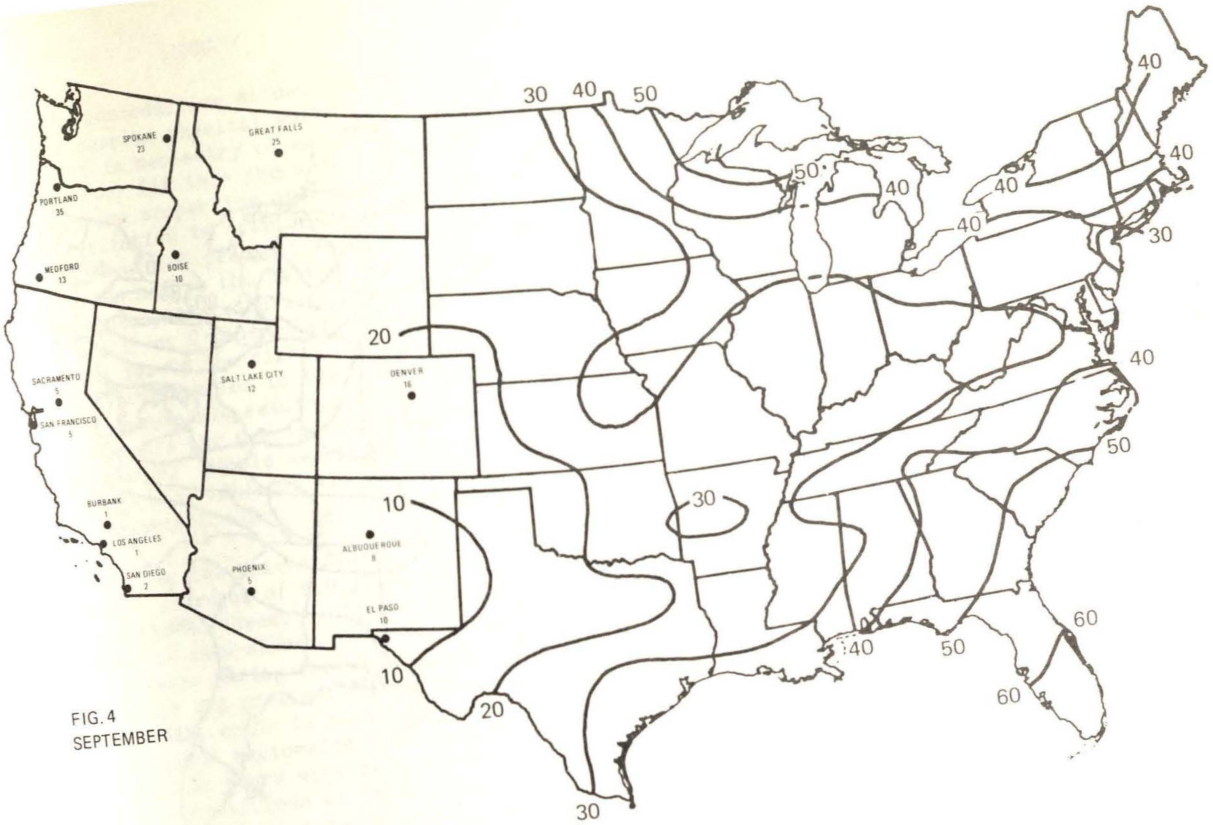

FIG. 4
SEPTEMBER

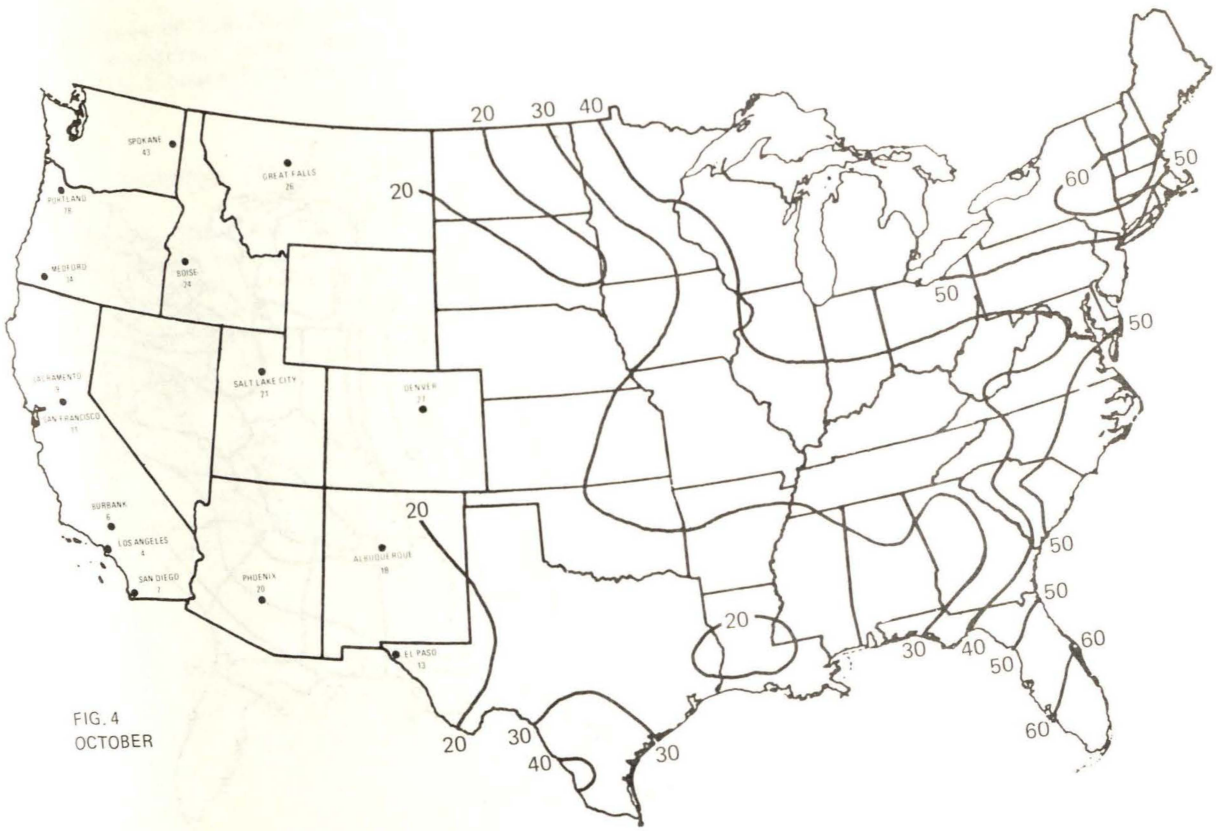

FIG. 4
OCTOBER

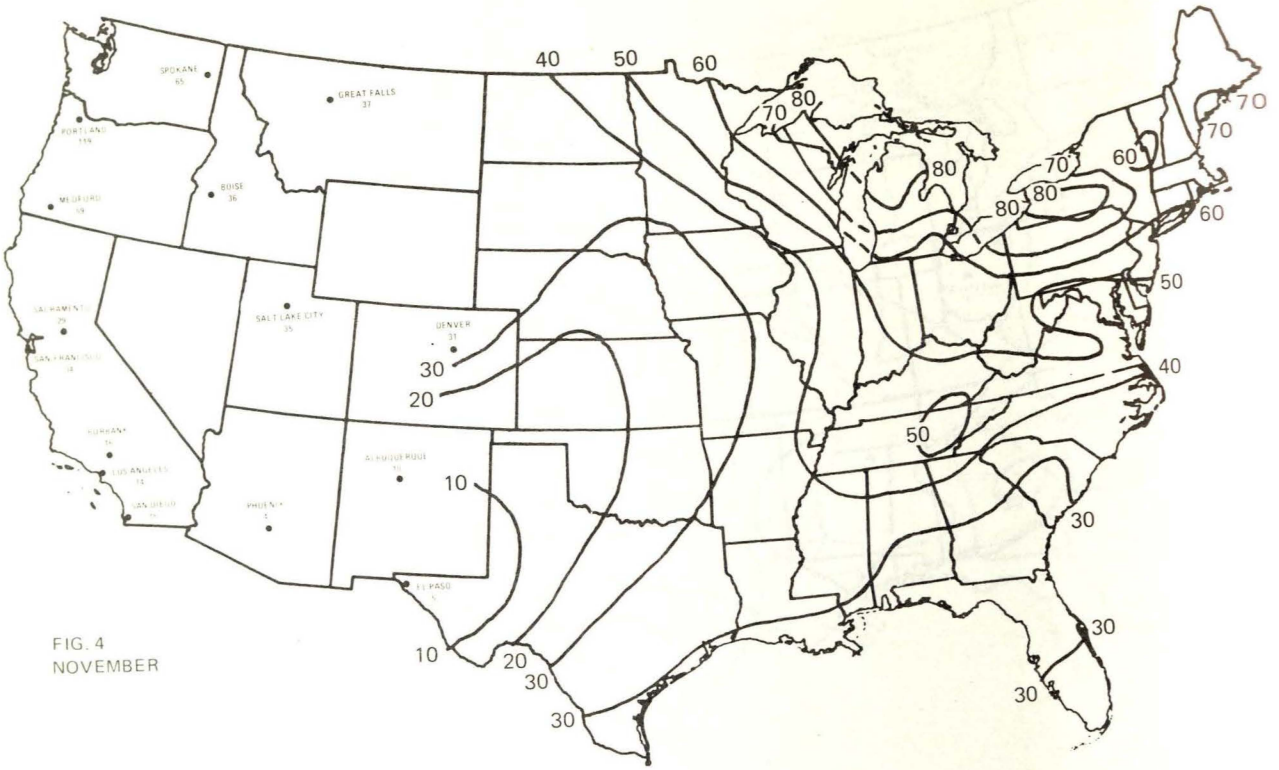

FIG. 4
NOVEMBER

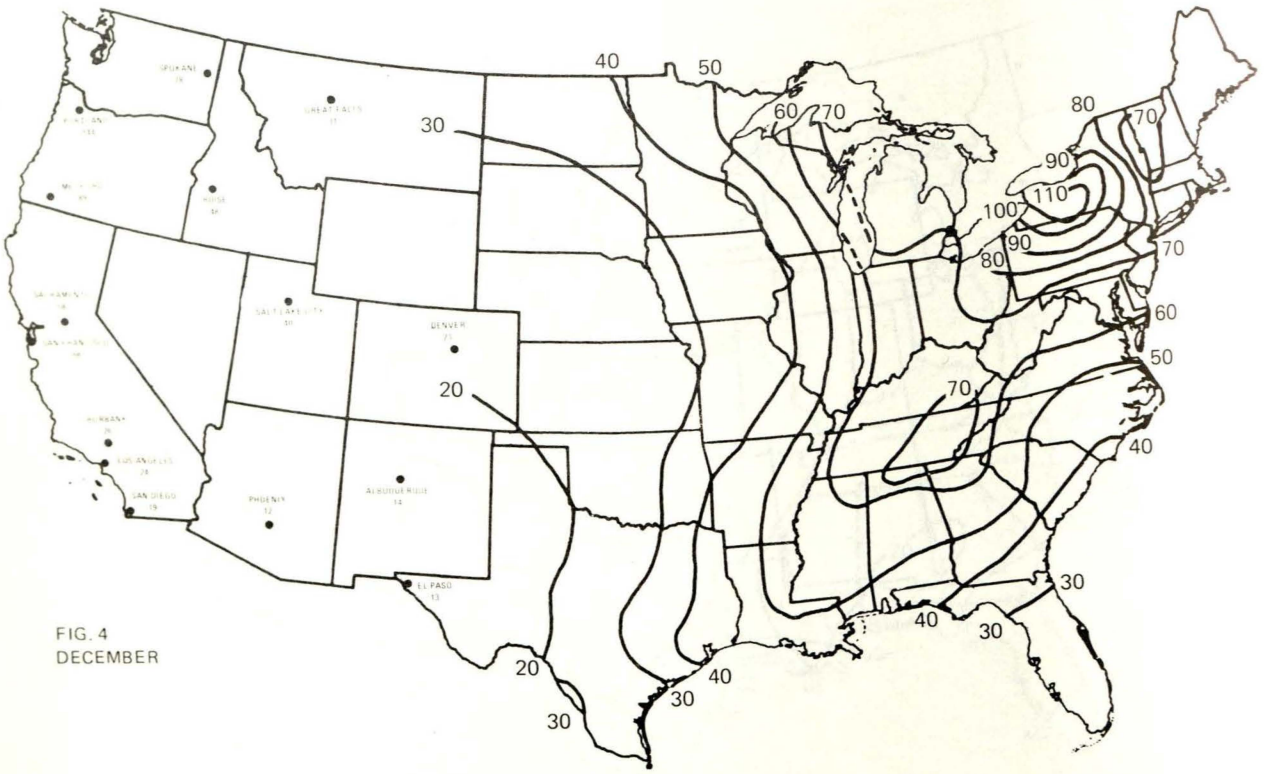

FIG. 4
DECEMBER

SUMMARY

With the introduction of new models to describe the complex physical world (such as the new NFDRS), it is necessary to examine physical variables as they fit into the models. Because of the absorption properties of fuels, exposure time to precipitation is critical. An examination of total hours of precipitation per day from 11 stations across the United States shows a J-shape frequency distribution. The mode is located at the 1- or 2-hour group with the curve trailing far to the right. Fitting a gamma-probability function to the data gives average, 50th-percentile readings of about 3.3 precipitation-hours per precipitation-day during major fire-seasons. Simple averaging of the same data produces a value of 4.7 precipitation-hours per precipitation-day.

Mean maps for the United States show the highest spatial averages of P.H./P.D. in the Northeast and the Northwest. Highest monthly averages occur as snow-shower phenomena with greatest occurrence during the winter and early spring. Annually the greatest number of precipitation-hours occur in these same two geographic regions. Nationwide patterns of the "mean number of hours with precipitation" are similar to computations of "mean number of days with 0.01 inch or more of precipitation" (U.S. Dep. of Commerce, NOAA 1968).

A good estimate of P.H./P.D. can be derived from the included charts. During major fire-seasons subtract 1.5 hours from the given map values.

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Examines aspects of precipitation-hours per unit time. Presents nationwide patterns of mean precipitation-hours per month as well as precipitation-hours per precipitation-day.

OXFORD: 111.772:431.1:432.2:432.5(73). KEY WORDS: precipitation duration, gamma probability function, fire danger rating, fire weather.

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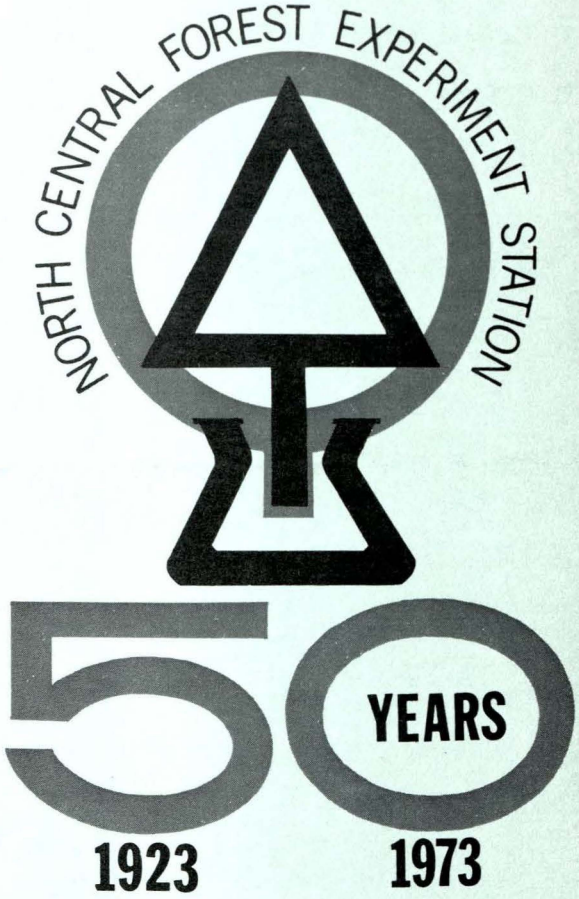
NORTH CENTRAL FOREST EXPERIMENT STATION
50
YEARS
1923
1973